

## Sabatier Carbon Dioxide Reduction Assembly Development for Closed Loop Water Recovery

The Sabatier Carbon Dioxide Reduction System (CRA) offers water recovery on a long duration space mission to reduce water resupply. Currently, NASA Johnson Space Center (JSC), NASA Marshall Space Flight Center (MSFC), Hamilton Sundstrand Space Systems International, Inc. (HSSSI), and Southwest Research Institute (SWRI) are working together to develop a Sabatier CRA for the International Space Station (ISS). This effort is being funded by the Office of Biological and Physical Research (Code U) / Advanced Life Support program which is administered by NASA JSC.

The Sabatier CRA is the next step in closing the oxygen life support loop on future space missions. The Sabatier reaction combines the waste carbon dioxide (recovered from crew metabolism) with waste hydrogen (a byproduct of electrolysis to produce oxygen) to produce water and methane ( $\text{CH}_4$ ). On ISS, the methane would be vented overboard, however the methane can be utilized for propulsion during a planetary exploration mission. Based on a crew size of 7-equivalent people, the Sabatier CRA can produce as much as 2000 lb/year water. Use of the Sabatier CRA will significantly reduce the amount of water that needs to be resupplied to the ISS on a yearly basis, at a tremendous cost saving to the program. Additionally, by recycling this additional water, the Sabatier CRA enables additional launch capacity for science experiments to be brought up to the ISS.

The NASA / Industry team noted above has been working to reduce technical risks associated with the Sabatier CRA system. To date the technical risks have been considerably reduced, bringing the Technology Readiness Level (TRL) from TRL 4 to TRL 5/6. In doing so, the team has developed the system schematic, system models, control scheme, produced engineering development unit (EDU) hardware, performed limited integration testing of the EDU's and verified system modeling through testing. Additionally, the system schematic has been evaluated for failure modes and hazards and had a successful technical review by the NASA Safety Board. The current focus is now related to development of the water/methane phase separator, liquid sensor and  $\text{CO}_2$  compressor piston seal life. The overall goal of the current effort is to bring the system up to a TRL6 by the end of GFY04.

Although the Sabatier CRA is not currently baselined for use on the ISS, its benefits are significant enough such that volume within the Oxygen Generation System rack has been reserved for future installation. The value of the water the CRA recovers will allow NASA the additional crew time and payload needed to pursue its mission of scientific research.

Sponsor:

NASA's Office of Biological  
and Physical Research

Advanced Life Support Program

Sabatier Carbon Dioxide Reduction Assembly  
Development for Closed Loop Water Recovery

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AMES RESEARCH  
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Government /  
Industry Team



HAMILTON SUNDSTRAND  
SPACE SYSTEMS INTERNATIONAL

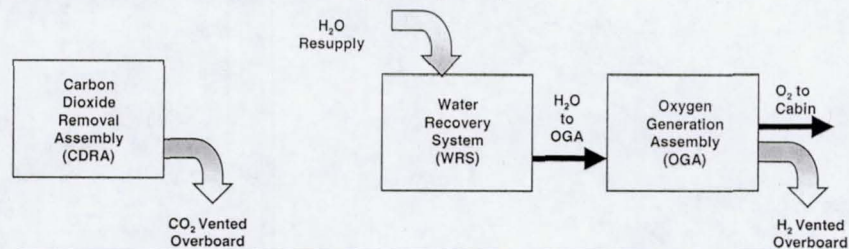
Southwest  
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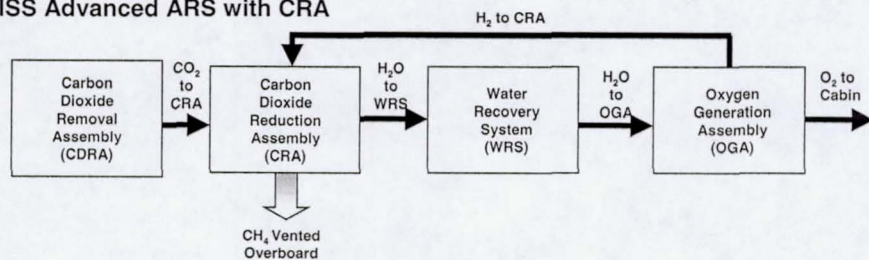
ISO 9001

## CO<sub>2</sub> Reduction Closes the O<sub>2</sub> Loop

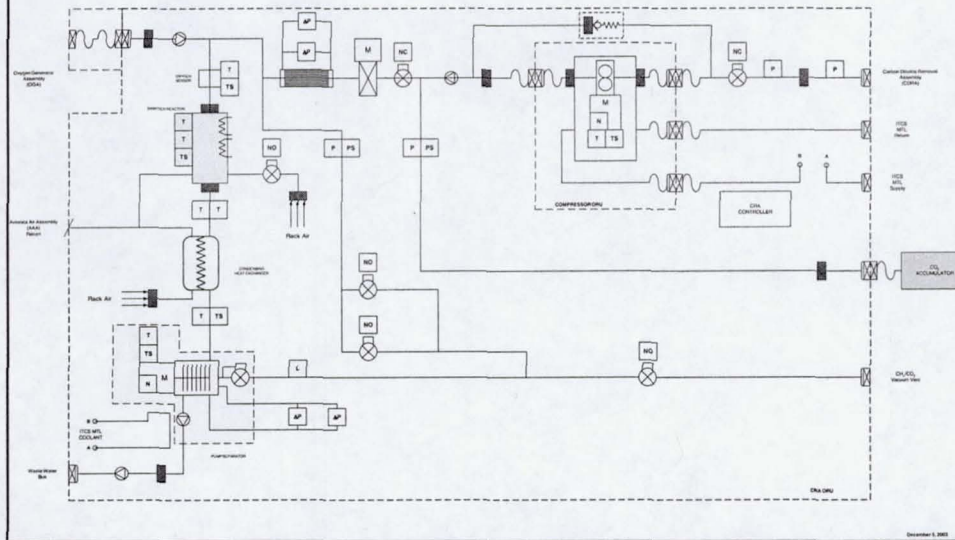
ISS Baseline Air Revitalization System (ARS)



ISS Advanced ARS with CRA



## Carbon Dioxide Reduction Assembly (CRA) Schematic



## ALS Funded CRA Development Activities

- System modeling and simulation
- System integration development
- Generation of schematic, ICD and specifications
- CO<sub>2</sub> Compressor development
- Component development and test
- Oxygen Generation System (OGS)  
  Rack scar definition and implementation



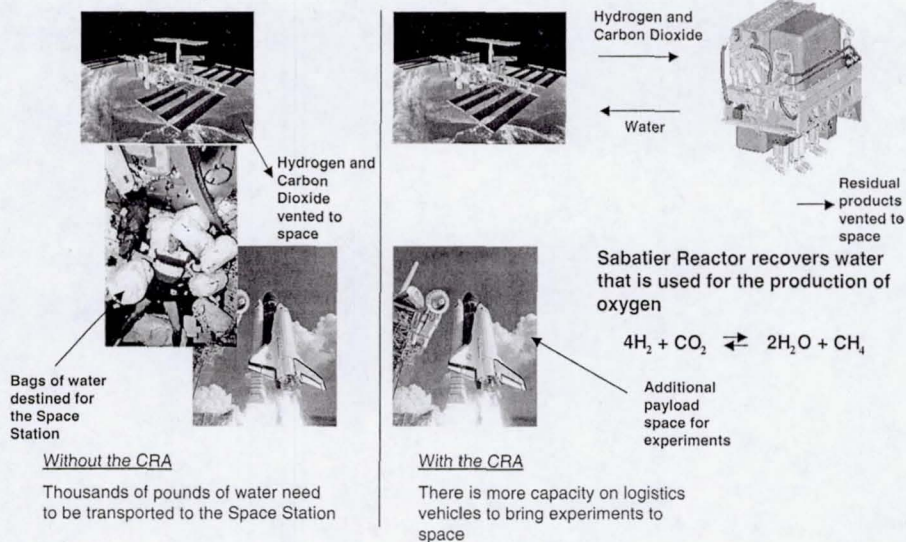
## CRA Technology Readiness Level

Core Components	Current Status	Development Necessary to Reach TRL 6	Expected Timeframe
<b>Sabatier Reactor</b>	<b>TRL 5:</b> The bed diameter, length, heating cooling and bed retention have many years of successful testing.	Integral filter to trap fines, tolerance to poisoning, materials of construction, vibration and heat transfer isolation.	FY04 to start of flight program
<b>Condensing Heat Exchanger</b>	<b>TRL 5:</b> Demonstrated in 1-g environment. Shape and location are second order.	Materials of construction, mounting.	Flight program
<b>Phase Separator</b>	<b>TRL 5:</b> The phase separator follows the pedigree of the Oxygen Generation Assembly - Rotary Separator Assembly.	Must be tested for tolerance to freezing and fines. Must be able to startup without pumping gas to water bus. Must develop separate pump to complement separator.	FY04
<b>CO2 Compressor</b>	<b>TRL 5:</b> Piston compressor has been developed to TRL 5 under Space Station Freedom program.	Materials, acoustic performance, and seal life require further development.	FY04

Ancillary Hardware and System Maturity	Current Status	Development Necessary to Reach TRL 6	Expected Timeframe
<b>Ancillary Components</b>	<b>TRL 5:</b> System has been demonstrated with off-the-shelf components. Some components not yet proven to work from system control and performance point-of-view.	Development of the modulating CO <sub>2</sub> valve, latching valve, outlet regulator, product water pump and liquid sensor.	FY04
<b>Hazardous Gas Containment</b>	<b>TRL 5:</b> A seal approach has been determined for the CRA that addresses leakage and maintainability.	This approach must be reduced to practice to determine if the leakage values assigned to connections are reasonable.	Flight program

Control and Control Integration	Current Status	Development Necessary to Reach TRL 6	Expected Timeframe
System Model	<b>TRL 4:</b> A system model has been developed of the Sabatier reactor system. The Sabatier EDU operates off of a commercial controller that has not been interfaced with the plant model.	This model must be expanded to include the OGA and the CDRA with the CO <sub>2</sub> compressor. The EDU must be interfaced with the other subsystems to complete the control design.	FY04
Safety Analysis	<b>TRL 4:</b> Informal presentation of concept to White Sands Test Facility and NASA JSC Safety Board with agreement on approach	Formal presentation to the NASA JSC Flight Safety Board with approval of schematic and controls	Flight program

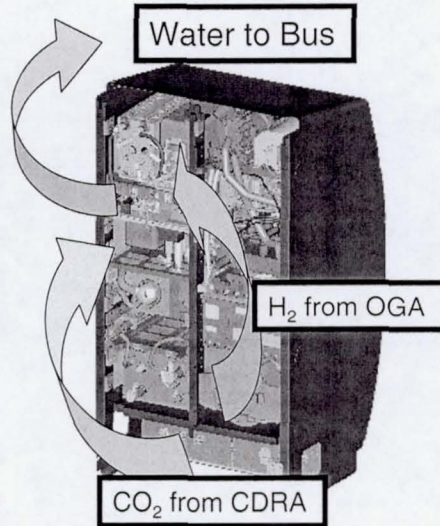
## CRA Water Recovery System





## Where CRA Fits into Node 3

- CRA further closes the oxygen loop
  - Utilizes waste hydrogen from the Oxygen Generation Assembly (OGA)
  - Utilizes waste CO<sub>2</sub> from Carbon Dioxide Removal Assembly (CDRA)
  - Combines H<sub>2</sub> and CO<sub>2</sub> to make water and methane
- ISS Node 3 OGS rack scarred to accept CRA
  - Envelope
  - Interfaces
  - Accumulator



## CRA Benefits to ISS

### Operational Payback

#### Risk Mitigation

- Use of Sabatier lessens dependence on ground resupply
- CRA produces 2040 lb/year (equivalent to 2 shuttle flights)
- Free-up Payload Space for science experiments (Progress, HTV, ATV)
- Provides contingency for water quality upsets on vehicle
- Future Shuttle replacement vehicle may not have fuel cell water available

#### Water Payback

- ISS operates at a deficit of 4521 lb/year (Crew of 6 + animals equivalent to 1.25 crew)

#### Crew Time

- Currently water deficit is made up by transferring water via CWC's and Progress resupply capability
- In the future, H<sub>2</sub>O deficit to be made up by shuttle, Progress, HTV, ATV

### Technology Development Payback

#### Technology Development

- Sabatier CRA next step in closing O<sub>2</sub> loop to save water on ISS
- Sabatier technology is critical to advancing future exploration missions
- Scientific experiments can be launched instead of water

## ISS Annual Water Logistics Summary

	Crew of 6 (+ animals) Figures in lb water/year	
	without CRA	with CRA
Water required for ISS Oxygen generation	5856	
Water required for ISS Activities	16,055	
Water supplied by Water Processor	-17,390	
Deficit	4,521	
Water provided by CRA	0	2040
Water scavenged from Shuttle fuel cells (3800 lbs available from 4 flights/year)	3800	2481
Water required to be Launched	721	0

Expendable weight of CRA (1 new compressor every 2 years)

**Net yearly launch weight**

0

721

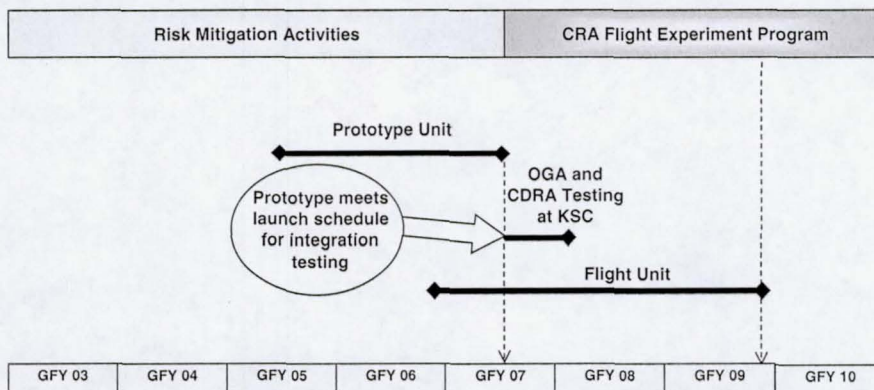
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**Total yearly launch weight savings for a crew of 6 w/ animals = 685 lb**

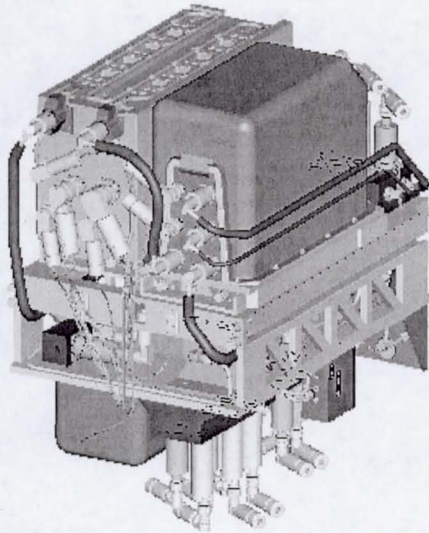
One time launch weight of CRA = 450 lb

## CRA ISS Program Schedule Highlights

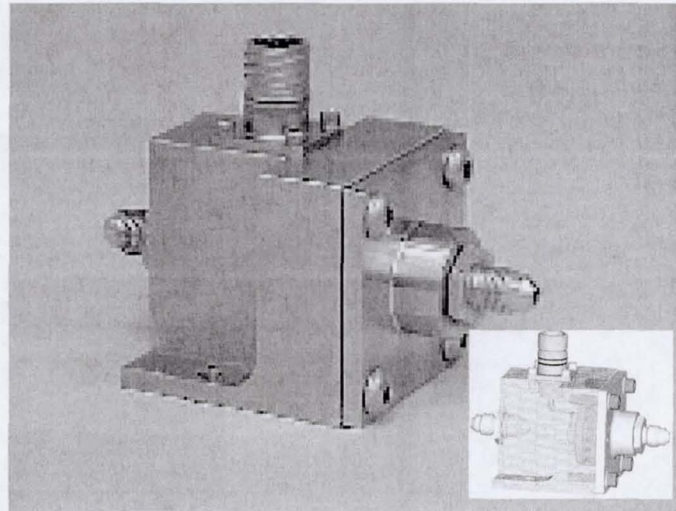


*Ground integration is the ultimate risk mitigation activity*



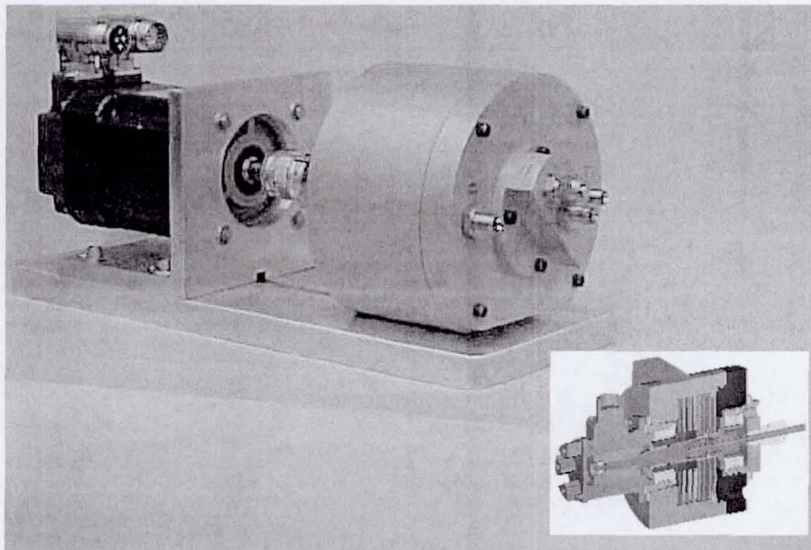


- CRA is a component of a closed loop life support system that recovers water from waste products
- CRA collects and stores  $\text{CO}_2$ , meters it to combine with hydrogen in a reduction reactor, condenses the product, separates the water from the waste gas and delivers the product water to the Waste Water Bus



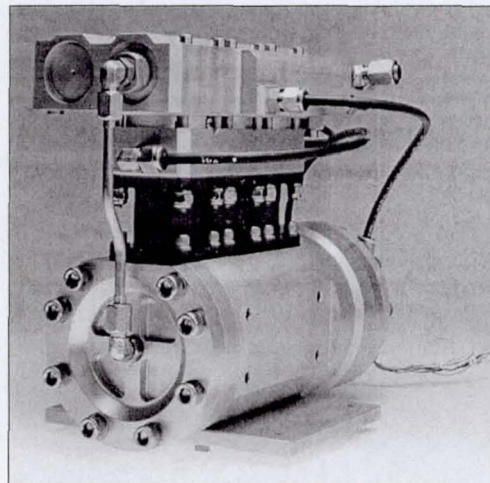
**Liquid Sensor**

A development liquid sensor is currently being built and tested.



#### Phase Separator

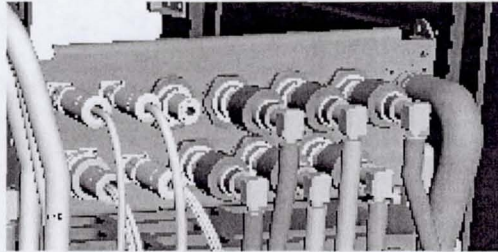
Proof-Of-Concept unit verified separator performance and showed the need to develop a pump. Pump development is in process.



#### CO<sub>2</sub> Compressor

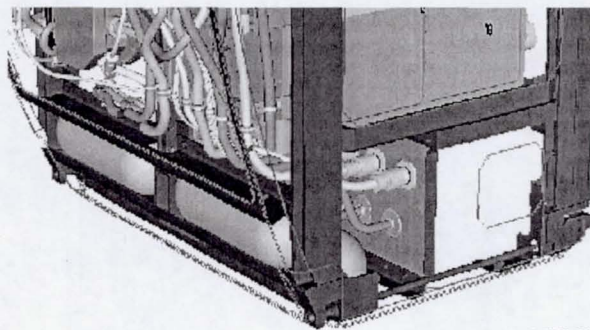
A Prototype CO<sub>2</sub> Compressor was tested to evaluate piston seal wear. A second wear test is ongoing. An Engineering Development Unit is being built.





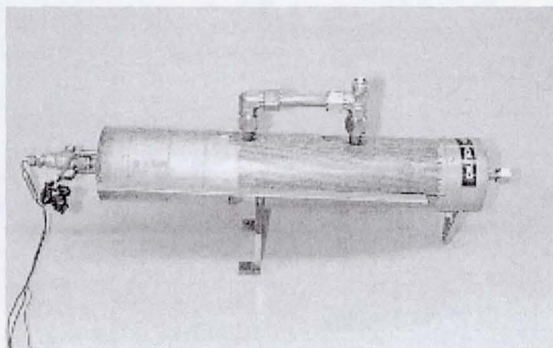
**Rack Scar Bracket**

Rack Scar has been defined with implementation underway



**CO<sub>2</sub> Accumulator**

The CO2 Accumulator has been defined with implementation underway



#### **Sabatier Reactor**

The Sabatier Reactor has been developed by Hamilton Sundstrand. Further testing for development of fines filtration and tolerance to poisoning are underway.





American Institute of  
Aeronautics and Astronautics

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*Habitation\**, an International Journal for Human Support Research, the National Aeronautics and Space Administration (NASA) and the American Institute of Aeronautics and Astronautics (AIAA) are pleased to announce "Habitation 2004", an international conference on space habitation research and technology development, to be held at the Rosen Plaza Hotel in Orlando, Florida, January 4-7, 2004.

"Habitation 2004" will bring together scientists and engineers engaged in research and technology development that enables long duration missions for human exploration of space. This conference will be an open forum that provides an opportunity to present research results and share data and other information.

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\* Formerly known as *Life Support and Biosphere Science*, an International Journal of Earth and Space.